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ARTICLE



The effect of lean on occupational health and safety and productivity in the garment industry – a literature review

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ABSTRACT

Introduction: Lean is increasingly used by garment manufacturers to increase productivity for reducing costs and lead time. Yet, it has not been documented in a review whether lean actually improves productivity, and it is an open question whether lean can improve productivity without jeopardizing occupational health and safety (OHS).

Objective: This article contributes to this debate by reviewing the present knowledge about the effect of lean on productivity and OHS in the RMG industry.

Methodology: A systematic review of the available peer-reviewed studies of lean in RMG and its related effects on productivity and OHS.

Results: We identified 18 relevant articles, which showed strong positive effect of lean on productivity and weak positive to mixed effects of lean on OHS.

Conclusions: Our results indicate that lean in RMG is likely to improve productivity, but RMG manufacturers need to make careful assessment of the effect of lean on OHS and adjust lean implementation accordingly.

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Lean; OHS; repetitive strain injuries; productivity; apparel

1. Introduction

The readymade garment (RMG) industry is a labour-intensive low-skilled assembly industry, which has motivated international brands for outsourcing their production to low-wage developing countries in Asia, Africa and South America. Recently, international buyers have shifted a part of their production from China to Bangladesh, Myanmar, Cambodia and Ethiopia, seeking even cheaper labour force. However, the industry has realized that outsourcing to countries with a cheap labour force is far from securing a permanent competitive advantage and the possibility to shift continuously the production to countries with even lower salaries will be exhausted soon. As a consequence, international buyers are increasingly inducing garment manufacturers in developing countries to adopt new manufacturing systems for productivity and quality improvements (Kader & Akter, 2014). A key system for this endeavour is lean manufacturing, which is based on ‘The Toyota Production System’ or TPS originating in Japan (Liker, 2004; Ohno, 1988; Spear &

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Bowen, 1999). The main objective of lean is to eliminate waste by reducing or optimizing supplier, customer, and internal variability (Shah & Ward, 2007). Lean has been widely applied in industrialized countries where, in spite of implementation constraints, it has proven to be a valuable method for productivity development (Gupta & Jain, 2013). However, much less is known about lean in developing countries and particularly in a labour-intensive industry as RMG.

Moreover, although the development of the RMG industry has had a positive impact on the economy of the developing countries and on creating a large number of low-skilled jobs, the industry has often been criticized for underpayment, long working hours, and unsafe and unhealthy working conditions (Islam, 2015). The criticism intensified in the wake of major accidents in the garment industry in developing countries, such as the Rana Plaza accident in Bangladesh in 2013. As consequence, the pressure from international brands and the international community pushed for the improvement of OHS in the garment factories. Nowadays, there is an effort among garment manufacturers in several developing countries to improve productivity and OHS conditions simultaneously (Locke, Qin, & Brause, 2007; Locke & Romis, 2007).

Yet, it is far from evident that lean will have a positive impact on OHS in RMG. Indeed, the impact of lean manufacturing on OHS has been heavily debated in developed and industrialized countries (Stewart et al., 2009), and some voices proclaimed lean to be mean already in the early implementation stages (Harrison, 1994). Yet, other authors have argued that lean is beneficial for the OHS, workers' behaviour, and work environment (Gaiardelli, Resta, & Dotti, 2018; Sakouhi & Nadeau, 2016; Womack & Jones, 1996). A review of the literature (Hasle et al., 2012) indicated that there were no many empirical studies of the effects of lean on OHS, and that the outcomes of lean implementation on OHS conditions, to a great extent, depended on the context and the way lean was applied. However, the review found a clear tendency of negative impact of lean on OHS in manual assembly work in the manufacturing industry, which resembles the characteristic of sewing in the RMG industry. More recent studies have indicated that the relationship between operations and OHS priorities can be contradictory or complementary depending on the joint management of the two priorities (Pagell, Klassen, Johnston, Shevchenko, & Sharma, 2015; Tompa et al., 2016). It is, therefore, still an open question how lean and OHS interact, and, particularly, the relationship between lean and OHS is far from understood in the context of the RMG industry in developing countries.

This paper narrows this gap through a systematic literature review of studies relating lean and OHS as well as productivity outcomes in the RMG industry. While we find a strong support for the effect of lean on productivity, our results point to a weak positive to negative association between lean and OHS. The paper recommends further research in order to identify possibilities the development of more positive associations between lean implementation and OHS.

The next section presents the background of the study followed by a description of the structured literature review. The remaining sections present the results followed by discussions and conclusion.

2. Background

RMG is considered as one of the most labour-intensive industries in the world, which motivates RMG industries to locate in countries where labour is available in abundance. China is the largest supplier of RMG to the world followed by other Asian countries such as Bangladesh, India, Sri Lanka, Vietnam, Cambodia and Indonesia. The majority of these countries are clearly identified by cheap labour availability in a growing economy and share common problems, such as lack of trained workers, inefficient mid-level management, low productivity and poor working conditions (Hasnin & Ahsan, 2016; Rakib & Adnan, 2015).

China's RMG industry started back in 1949. In the earlier years, the Chinese RMG industries suffered from low productivity until the economic reforms in 1978. Subsequently, by 2000, the Chinese RMG gained advantage and was able to capture one fifth of the global market share (Zhang, Kong, & Ramu, 2015). Occupational hazards were common in the RMG industry in China and the country started to adopt legislative measures to improve workers safety (Zhang, Wang, & Li, 2010). However, in the last 10 years, the prevailing cost advantage in China became obscure, and in consequence, many garment companies started to exploit opportunities in other growing Asian markets in order to hold down costs and to reduce overdependence on China (Witchell & Symington, 2013).

In this context, Bangladesh has emerged as the biggest gainer from the Chinese industrial shifts and assumed the position of the second largest garment exporter in the world. But in terms of productivity, the performance of the Bangladeshi garment industry is below the mark and buyers point to late delivery as one of the main issues of the industry (Kader & Akter, 2014). In addition, poor OHS conditions are considered among the important reasons for lower productivity in Bangladesh (Berg, Hedrich, Kempf, & Tochtermann, 2011; Nargis, 2013; Saha & Mazumder, 2015). Moreover, the productivity of the garment industry in Bangladesh is lower in comparison not only to China but to other Asian countries as well. In response to low productivity, garment manufacturers in Bangladesh are focusing on productivity improvement of their plants by applying lean tools such as proper line balancing, time study, and housekeeping (Islam & Adnan, 2016).

Furthermore, adherence to social compliance standards is also lower in Bangladesh than in competing regional countries (Baughn, Bodie, & McIntosh, 2007; Maalouf, Hasle, Vang, & Hoque, 2019). Indeed, in addition to the focus on productivity and efficiency, the RMG industry in Bangladesh is striving to improve workplace safety for the millions of garment workers in compliance with the national and international labour standards and labour rights (Ansary & Barua, 2015). Moreover, on the wake of incidents like Rana-plaza and Tazreen fire, pressure from the international buyers and legislators increased dramatically and pushed the garment industry towards stricter compliance with norms and regulations related to workplace safety and workers' rights (Hasnin & Ahsan, 2016; Rahman & Hossain, 2010).

As for other Asian and African countries such as Sri Lanka, India, China, and Jordan, they have also adopted lean manufacturing system in order to meet global business challenges. In this context, available studies revealed benefits and issues of lean implementation on work conditions (Al-Jawazneh, 2011; Chiromo, Nel, & Sebele, 2015; Gamage, Vilasini, Perera, & Wijanatha, 2012; Raju & Mahato, 2014; Taj, 2008).

2.1. Lean philosophy and its possible effects on OHS

Lean has a long history from Taylor's scientific management in the early twentieth century to TPS (Liker, 2004). It was adopted by American automakers as an attempt to increase the competitiveness of the American auto industry in the late 1980s (Womack & Jones, 1996; Womack, Jones, & Roos, 1990), and it has today found a wide application in manufacturing and many other industries. Lean manufacturing is a system that greatly influences organizational performance and culture (Pakdil & Leonard, 2015), but it is also a much debated concept without a commonly agreed definition, which varies from a general production philosophy to a list of practical tools (Shah & Ward, 2007). The promises of lean are not always fulfilled (Vest & Gamm, 2009), which is often explained by implementation failures (Sparrow & Otake-Ebiede, 2014). Still, lean system is widely used in both manufacturing and service industries, and even though a deep lean culture is rare to find, many lean tools or bundles of tools are applied in practice. Yet, the effect of lean on the productivity of the garment industry, which is unlike studies of lean in other industries mainly located in developing countries may not be taken for granted. The short experience with manufacturing industry and low qualifications of both managers and workers may enhance the well-known implementation failures of lean. It is, therefore, pertinent to review the available studies of effects of lean on productivity in the RMG.

A common problem in manufacturing industries surfaces when increases of productivity are achieved at the cost of the health and safety of the workers (Von Thiele Schwarz, Hasson, & Tafvelin, 2016; Westgaard & Winkel, 2011). The reasons for prioritizing productivity over OHS include lack of knowledge, cost of application, and the separation of OHS priorities from core business goals and daily operations. Yet, the same studies show that, when operational improvements are integrated with safety priorities, the overall business performance improves (Abad, Lafuente, & Vilajosana, 2013). While some studies found evidence that lean has a negative effect on OHS (Landsbergis, Cahill, & Schnall, 1999; Stewart et al., 2009), others indicated that there may be both positive and negative effects of lean on OHS (Hasle, 2014). Yet, there are particular good reasons to be aware of the negative effects of lean especially in repetitive assembly work (Brännmark & Håkansson, 2012; Hasle et al., 2012). Indeed, it is well established that repetitive work is a risk factor for the development of repetitive strain injuries (RSI) (Buckle & Jason Devereux, 2002; Muggleton, Allen, & Chappell, 1999). For RMG, it is also convincingly proven the repetitive tasks of sewing machine operators carry a high risk of RSI (Ozturk & Esin, 2011; Sealetsa & Thatcher, 2011; Vezina, Tierney, & Messing, 1992). The question is, therefore, what effects lean may have on the risk of RSI as well as other occupational injuries.

3. Methodology

The study uses a systematic literature review approach (Grant & Booth, 2009) in order to identify and analyse relevant studies focusing on the relationship between lean implementation and OHS and productivity outcomes in the RMG industry. We followed a standard procedure for the literature search, data extraction, and synthesis as outlined below. The research team was composed of three researchers based in Bangladesh and Denmark. The researchers decided jointly at the start of the study about search terms, definitions and the research questions.

The literature search included empirical studies published in peer-reviewed international journals applying both qualitative, quantitative and mixed-methods articles that focused on the relationship between lean, productivity and OHS in the RMG industry. We started the literature search using the following three strings:

String 1: Garment, textile, clothing, apparel, RMG

String 2: Lean, value stream mapping, kaizen, 5S

String 3: OHS, occupational health and safety, safety, ergonomics, occupational health

However, we obtained only two studies that meet the criteria. Then, we decided to include only String 1 and String 2 from three databases: Business Source premier, Scopus, and Web of Science. The strings were used in all databases with appropriate truncations and Boolean operators, such as AND and OR.

The inclusion criteria are:

- Articles considering lean implementation in the RMG
- English language articles
- Peer-reviewed journal and articles that include empirical data
- Articles published in the period of 1990–2019

Afterwards, three reviewers independently screened the selected titles and abstracts of the 94 eligible articles. We have excluded articles focusing on topics such as textile machinery, garments product design, chemical barrier, ergonomic clothing comfort, garments trade regulation, and cloths classification (26 articles excluded). Then, the search results from each database were merged and duplicates deleted (11 articles deleted). Afterwards, in the screening phase, we read the whole text and used the following inclusion criteria: articles focusing on the effects of lean implementation on productivity and/or OHS in the RMG sector. We also excluded articles, which have insufficient information about methodology and/or results. We ended up with 14 articles focusing on the effect of lean implementation on productivity and/or OHS.

Then, a crosscheck by Google Scholar and the references and citations of selected articles was performed in order to capture the maximum number of hits. We added four articles originated from the crosscheck of Google Scholar and the citations and references of the selected 14 articles. We finally obtained 18 articles for the systematic review (see [Figure 1](#)).

Following recommendations in the literature (Hasle et al., 2012), three researchers assessed the quality of these 18 articles independently according to four classifications: (1) positive association with productivity; (2) negative association with productivity; (3) positive association with OHS; (4) negative association with OHS. For each of the four classifications, we assessed the relationship as ‘strong’ or ‘weak’ association.

- (1) *Strong evidence for a positive (AA) or negative (BB) association:* We assessed the effect of lean implementation on OHS and productivity as strongly positive association (or strong negative), if the study uses robust methods including statistical analysis, multiple case study, controlled experiment, and mixed methods.
- (2) *Weak evidence for a positive association (A) or negative (B) association:* We assessed the effect of lean implementation on OHS and productivity as weakly positive (or weak

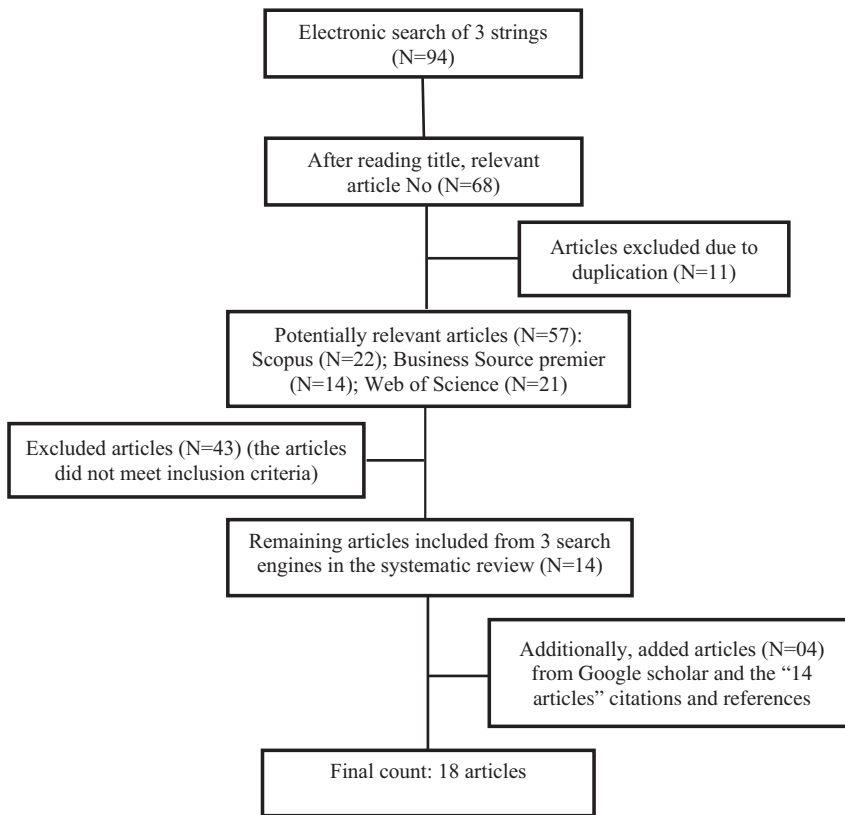


Figure 1. A summary of systematic search and review process.

negative), if the results are not statistically significant or exclusively qualitative single case studies or weak methodology.

- (3) *Assessment (N)*: Outcome measures presented with no information about OHS or productivity results.

4. Results

4.1. Summary of results

Table 1 describes the main characteristics of the 18 articles identified by the systematic search. As for the used research methods, 10 articles used survey methods and quantitative analysis. In these 10 articles, the number of participants varied from 100 to 1189 participants, and the number of participating organizations varied from 3 to 31. Seven articles used qualitative methods. Hereof, five used single case studies and two used qualitative interviews involving 8 and 11 garment plants, and finally one single case study employed and experiment at the shop-floor level.

As for the focus of the studies, nine articles explored the whole garment production process from cutting to packaging, one article focused on quality management, and one article reported the results of an experiment in the sewing line. The remaining seven articles focused on selected activities in the factory such as cutting, sewing, finishing, spinning, total productive

Table 1. Description of the reviewed articles.

No.	Author	Method	Focus	Lean practices	OHS practices	Outcome measures in the study
1	Wickramasinghe and Wickramasinghe (2011b)	Questionnaire (survey): 616 respondents in 12 plants	The whole garment production process from cutting to packaging	Bundle of lean practices (unspecified)	None	-Turnover intention -Job involvement -Perceived organizational support -Cut-ship time -Dock-to-dock time -On-time delivery -Accepted quality level (AQL) -Defects -Efficiency -5S score -Work in progress (WIP)- Unnecessary activity -Intensity of adoption of lean -Teamwork and commitment of workers -Efficiency -WIP -Defects -Movement of workers -Efficiency -Inventory -Cleanliness -Workstation design (unspecified) -Cost-effectiveness -Product quality -On-time delivery -Volume flexibility -Incident of injuries and accident -Efficiency -Lean duration -Workers' participation
2	Quddus and Nazmul Ahsan (2014)	Controlled experiment in one sewing line	One sewing line	Kaizen event, 5S, Defects per hundred units (DHU)	5S	
3	Kaur et al. (2016)	Comparative study of 10 lean and 10 non-lean plants	The whole garment production process from cutting to packaging	Bundle of lean practices (5S, TOM, TPM, JIT, Visual Management)	5S, work force orientation	
4	Vijayakumar and Robinson (2016)	Case study in eight plants	The whole garment production process	5S and Cause and Effect diagram	5S	
5	Kumar et al. (2019)	Case study in a single plant	Production floor (sewing lines)	VSM 5S Line Balancing	5S	
6	Wickramasinghe and Perera (2016)	Questionnaire (survey): 236 respondents from 30 plants	Department of Total Productive Maintenance	TPM (Total Productive Maintenance)	Safety device	
7	Wickramasinghe and Wickramasinghe (2016)	Questionnaire (survey): 657 respondents from 14 plants	Kaizen workshop involving shop floor workers	Kaizen or continuous improvement	None	

(Continued)

Table 1. (Continued).

No.	Author	Method	Focus	Lean practices	OHS practices	Outcome measures in the study
8	Wickramasinghe and Wickramasinghe (2011a)	Questionnaire (survey): 745 respondents from 12 plants	Whole production process (shop-floor workers and managers)	Lean tools practices (not specified)	Organizational support and job involvement	-Lean duration -Propensity for participative decision-making (psychological factor) -WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness
9	Wickramasinghe and Wickramasinghe (2017)	Questionnaire (survey): 1189 respondents from 14 plants, and longitudinal data collected	All departments of an apparel and textile firm (survey of supervisors)	Bundle of lean tools (unspecified)	None	-WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness
10	Ahmed et al. (2018)	Questionnaire (survey): 100 respondents in 10 plants	Whole production process (raw material to finish goods)	6s	6s	-WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness
11	Gamage et al. (2016)	Questionnaire (survey): 318 respondents from 31 plants	Department of quality management	Taguchi's quality philosophy and practice, continuous improvement	None	-Theoretical model for Lean and TQPP (Taguchi Quality Philosophy and Practice) -Employee awareness -Efficiency -Inventory -5S score -WIP
12	Carvalho et al. (2019)	Case study in a single plant	Whole production process (raw material to finish goods)	VSM	None	-WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness
13	Hodge et al. (2011)	Qualitative interviews: 11 garments plant	Process of spinning, knitting, cutting, sewing and finishing	Kanban Application of lean tools with a special focus on VSM and 5S	5S	-WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness
14	Abeysekera and Illankoon (2016)	Questionnaire (survey): 128 respondents from three plants	Whole production floor and ergonomic analysis	5S, Kaizen, six sigma	Assessment of workplace conditions and ergonomics	-Sitting positions -Noise -Heat discomfort
15	Jackson and Mullarkey (2000)	Questionnaire (survey): 556 respondents from four plants	Quick response manufacturing (QRM) and progressive-bundle system (PBS) team	Quick response manufacturing (QRM) including U-Cell and visual management system	Assessment of psychological well-being	-Job satisfaction -Work conflicts -Multi-skilling -Absenteeism -Turnover -Inventory -Workstation design (unspecified) -Efficiency -Set-up time -Human fatigue -WIP -Worker fatigue
16	Silva (2012)	Case study in a single plant	Whole production process (from supplier to manufacturer to customer)	Value stream mapping (VSM)	None	-WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness
17	Marudhamuthu et al. (2011)	Case study in a single plant	Production floor (cutting and sewing)	Value Stream Mapping (VSM) and Single Minute Exchange of Die (SMED)	Workstation design	-WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness
18	Kumar and Sampath (2012)	Case study in a single plant	Production floor (Sewing lines)	VSM	Workstation design (U-shaped layout)	-WIP -Defects -Dock-to-dock -Workers' participation -Managers' participation -Defects -Worker movement -Cleanliness

maintenance department and different teams like quick response manufacturing (QRM) and progressive bundle system (PBS).

As for lean practices, all articles (18) focused on the implementation of different bundles of lean practices, such as 5S, Value Stream Mapping (VSM), Total Quality Management (TQM), Kaizen event, Total Productive Maintenance (TPM), Quick Response Manufacturing (QRM), Single Minute Exchange Die (SMED) and visual management. As for OHS practices, 12 articles reported practices such as worker involvement, participation, 5S, work station design and ergonomics.

Table 2 describes the productivity and OHS results and our assessment of the results. Eight articles found strong positive association between lean practices and productivity, while eight articles found weak positive association for the same relationship, and none found a negative association. As for the positive association between lean practices and OHS outcomes, five articles identified strong positive association, while other nine articles found weak positive association for the same relationship. As for the negative association between lean practices and OHS outcomes, one article identified strong negative association, while another article reported a weak negative association for the same relationship.

Table 3 presents a summary of distribution of the 18 studies according to the three categories of association.

4.2. Relationship between lean implementation and productivity

Table 1 reveals six major themes regarding the relationship between lean and productivity in the reviewed 18 articles. In the next sections, we present the relevant results within each of the six themes.

4.2.1. Production time

The articles focus on Production time, Cut-ship time, Dock-to-Dock time, On-time delivery, and Set-up time. Three studies found strong to weak positive association between lean and Cut-ship time, Dock-to-Dock time, On-time delivery, and one article found weak positive association between lean and Set-up time. For example, Kumar, Mohan, and Mohanasundaram (2019) found significant achievement of reduction cycle time and that is 34% and Wickramasinghe and Wickramasinghe (2011b) found evidence that cut-to-ship ratio increased 4% and 10% in two factories, Dock-to-Dock time reduced by 20 and 43 days in two factories, and On-time delivery ratio increased by 4% in one factory and 30% in another factory. Moreover, same authors report in another article, that dock-to-dock time was reduced by 33 days, cut-to-ship ratio increased 3% (from 96% to 99%), and on-time delivery increased by 4% (Wickramasinghe & Wickramasinghe, 2017). As for Set-up time, one study reports a reduction in one factory from 28 to 8 min (Marudhamuthu, Krishnaswamy, & Pillai, 2011). In another article, the authors (Wickramasinghe & Perera, 2016) found that reduction of defective tools replacement based on TPM had influenced positively on-time delivery.

4.2.2. Efficiency

Seven articles focused on the productivity of workers and line efficiency, and all studies involving productivity of workers and efficiency found strong or weak positive association between lean implementation and efficiency. Three studies show increased efficiency ranging from 12.5% to 90% (Carvalho, Carvalho, & Silva, 2019; Kumar et al., 2019;

Table 2. Results and assessment of association between lean, productivity and OHS.

No.	Author	Productivity results	Assessment of productivity results	OHS results	Assessment of OHS results
1	Wickramasinghe and Wickramasinghe (2011b)	-Cut-ship ratio increased -Dock-to-dock days reduced -Delivery on-time increased	A	-Job involvement increased -Employee turnover reduced	AA
2	Quddus and Nazmul Ahsan (2014)	-Productivity increased -Waste and defects were reduced	AA	-Unnecessary items removed -Easier reach and worker access -Clean floor and machine -5S score increased -Team work improved -Commitment of worker increased -Communication improved -Unnecessary motion reduced	AA
3	Kaur et al. (2016)	-Productivity increased in lean initiative plants	AA	-Clean workstation -Introducing floor layout -Number of injury and accidents decreased	A
4	Vijayakumar and Robinson (2016)	-Defect reduced	AA		A
5	Kumar et al. (2019)	-Lead time reduced -Efficiency increased -Inventory reduced	A		A
6	Wickramasinghe and Perera (2016)	-Improved productivity -Cost reduced -Product quality improved -On-time delivery -Volume flexibility increased -Productivity increased	AA		AA
7	Wickramasinghe and Wickramasinghe (2016)	-No information	AA	-No information	N
8	Wickramasinghe and Wickramasinghe (2011a)	-Waste reduced -Quality improved -Dock-to-dock time reduced -Productivity increased -Increased productivity	N	-Workers commitment and participative decision-making increased (psychological factor) -No information	A
9	Wickramasinghe and Wickramasinghe (2017)		AA		N
10	Ahmed et al. (2018)		A	-Reduced hazardous working conditions -Reduce worker movement - Cleanliness -Employee awareness increased -No Information	A
11	Gamage et al. (2016)	-Productivity increased	AA		AA
12	Carvalho et al. (2019)	-Efficiency increased -Inventory reduced -Waste decreased -Productivity increased	A		N
13	Hodge et al. (2011)		A	-Housekeeping improved	A

(Continued)

Table 2. (Continued).

No.	Author	Productivity results	Assessment of productivity results	OHS results	Assessment of OHS results
14	Abeysekera and Illankoon (2016)	-No information	N	Mixed results: -Lighting improved -Sitting positions, Noise and heat worsened	A, B
15	Jackson and Mullarkey (2000)	-Productivity increased	AA	Mixed results: -Absenteeism and turnover reduced -Job-related strain and conflicts among team members increased	AA, BB
16	Silva (2012)	-Waste identification	A	-No information	N
17	Marudhamuthu et al. (2011)	-Set-up time reduced -WIP reduced	A	-Fatigue reduced	A
18	Kumar and Sampath (2012)	-WIP reduced -Production lead time reduced	A	-Fatigue reduced	A

Note: AA = strong evidence for a positive association; BB = strong evidence for a negative association; A = weak evidence for a positive association; B = weak evidence for a negative association; N = no information.

Table 3. Summary of assessment results.

Assessment criteria	Strong association	Weak association	No information about productivity/OHS	Total number of articles
Positive association with productivity	8	8	2	18
Negative association with productivity	0	0	2	18
Positive association with OHS	5	9	4	18
Negative association with OHS	1 ^a	1 ^a	4	18

Note: ^aTwo articles reported mixed results (both negative and positive association between lean and OHS) in selected 18 articles.

Marudhamuthu et al., 2011; Quddus & Nazmul Ahsan, 2014; Wickramasinghe & Wickramasinghe, 2016). Less specific results were found in a Sri Lankan garment factory (Wickramasinghe & Perera, 2016) with improvements in the cost-effectiveness, product quality, on-time delivery and volume flexibility. Similarly, a comparison of two groups of lean and non-lean factories found that lean factories were more efficient than non-lean factories (Kaur, Marriya, & Kashyap, 2016).

4.2.3. Quality

Six studies focused on different dimensions of product quality: defects per hundred unit (DHU), zero defect, accepted quality limit (AQL) level, rework rate, and rejection rate. Even though the studies used different methods and approaches to the improvement of quality, they all found improvements. For example, in one article (Quddus & Nazmul Ahsan, 2014), the authors reported 62% reduction in a number of DHU (from 134 to 51 defects) in one of the factories. Vijayakumar and Robinson (2016) found that, after implementing 5S defective garment material reduced from 11.29% to 5.27% and applying same tool another author reported that, rework reduced 75% after 9 months (Ahmed, Islam, & Kibria, 2018). Another researchers found that AQL improved after lean implementation (Wickramasinghe & Wickramasinghe, 2011b, 2017). Moreover, Gamage, Jayamaha, and Grigg (2016) have found evidence that Taguchi's Quality Philosophy and Practice was positively related to lean manufacturing system and had positive effect on manufacturing quality outcomes.

4.2.4. Waste

Reduction of waste (Muda) through VSM is a key element in lean. Six studies identified wastes, such as WIP (work in progress) and inventory level, and considerable improvements could be achieved through VSM. Some studies reported a reduction of WIP ranging from 30% to 89% (Kumar et al., 2019; Kumar & Sampath, 2012; Quddus & Nazmul Ahsan, 2014). In another two articles, the authors reported 152% increase in value-added ratio, associated with the whole production process (from supplier to manufacturer to customer) (Silva, 2012) while Hodge, Goforth Ross, Joines, & Thoney (2011) reported an increase of 105% in value added activities.

4.2.5. Housekeeping

Five articles focused on housekeeping and 5S, and the studies show that applying 5S has several positive effects. For example, one study, Vijayakumar and Robinson (2016) investigated the effect of using 5S for reduction of defects and lead time. The authors reported a decrease in defect rate from 11.3% to 5.3% and a reduction in production

lead time from 81.5 to 74.7 h. In another study, indicate that 5S helps to reduce 54.67 m² space in a floor (Ahmed et al., 2018). In others, articles reported an increase in 5S audit score from 1.8 to 3.2 after applying 5S recommendations (Quddus & Nazmul Ahsan, 2014), better utilization of resources in cutting and sewing section (Kumar et al., 2019) and reduce the waste beyond the expectation (Hodge et al., 2011).

4.2.6. Intensity and duration of the adoption of lean practices

Five studies focused on the stages of implementation of lean practices and the tendency is that the longer duration of lean the larger impact. One of the articles found that most companies that adopted lean are in the initial phases of lean implementation (9 out of 10 plants). Only one plant had shown consistent lean implementation with visible results (Kaur et al., 2016). As for the duration of lean implementation, several studies indicated that the duration of the time of lean implementation had positive effects on workers' productivity, employees participation in decision-making, and managerial commitment (Jackson & Mullarkey, 2000; Wickramasinghe & Wickramasinghe, 2011b, 2016, 2017). In particular, early adopters of lean had a more established continuous improvement system. Moreover, Hodge et al. (2011) found evidence that a model for lean adoption including bundle of tools such as, VSM, policy deployment, visual management, continuous improvement, standardized work, just in time, is more likely to be successful in the garment industries than the implementation of individual practices.

4.3. Relationship between lean implementation and OHS outcomes

Three themes regarding the relationship between lean and OHS can be identified in the 14 articles (Table 1). In the next sections, we present the relevant results within each of the three OHS themes.

4.3.1. Housekeeping

Five articles focused on the impact of 5S on OHS during lean implementation. The studies show a clear tendency of 5S to improve ergonomics conditions especially by reducing unnecessary movements of workers. For example, number of article, the implementation of 5S improved material storage, which reduced unnecessary movements and ergonomic problems of workers (Hodge et al., 2011; Kumar et al., 2019). Moreover, one study observed that shop-floor and machine cleaning had positive effects on the respiratory system and general health of the workers (Quddus & Nazmul Ahsan, 2014). Other studies found that 5S implementation reduced unnecessary movements related to machine and table positions (Vijayakumar & Robinson, 2016) and reduced almost 20% movement in fabric and accessories room (Ahmed et al., 2018), which reduced the reach distance of materials and decreased musculoskeletal disorders and mental strain.

4.3.2. Ergonomics

Four studies focused on the effect of lean on human fatigue and ergonomic practices. The results are mixed with both positive and negative outcomes. Quddus and Nazmul Ahsan (2014) reported improvement in ergonomics as workers experienced a better fit into their workstations. Moreover, studies reported that VSM helped reduce human fatigue and effort by shortening the distance between cutting and production section (Kumar & Sampath, 2012;

Marudhamuthu et al., 2011). Yet, one study presented evidence that lean implementation had negative effects on OHS reflected in sitting discomfort, noise and heat (Abeysekera & Illankoon, 2016).

4.3.3. Worker engagement and participation

Five articles focused on the effect of lean on workers engagement and participation and reported both positive and negative associations. For example, one article presented evidence that organizational support during lean implementation increased job involvement, commitment, awareness and reduced turnover intention (Gamage et al., 2016; Kaur et al., 2016; Wickramasinghe & Wickramasinghe, 2011b). Other articles presented evidence showing that lean practices increased workers commitment and participative decision-making (Wickramasinghe & Wickramasinghe, 2011a, 2017), and reduced absenteeism and labour turnover (Jackson & Mullarkey, 2000; Wickramasinghe & Wickramasinghe, 2011b). Moreover, Locke and Romis (2007) found evidence that lean implementation had reduced task complexity and consequently increased employee participation. As for the negative effects of lean, Jackson and Mullarkey (2000) found evidence that lean implementation caused increase of peer pressure and conflicts among team members responsible for lean transformation.

5. Discussion

Our objective is to investigate the effect of lean implementation on OHS and productivity in the RMG industry. It is known that this industry has witnessed an increased competition especially in the form of shorter delivery time, smaller lots, frequent change of styles, and cost reduction. These developments have put extra pressure on garment manufacturers, which have adopted lean as an important tool to meet this pressure. Our literature review indicates that they do so with good reason. Indeed, all the studies show a positive effect of lean on the overall productivity. The studied garment manufactures have used a wide array of tools focusing on efficiency, waste reduction, change over time and quality, and all the applied tools have proven to have positive effects. Yet our review reveals that most lean initiatives are in the initial phases. Indeed, few factories have reached a high lean maturity level, and in many cases the studied lean initiatives are in the pilot phase, where long-term effects are uncertain, and there may be a risk that the effects may vanish when the initial interest and engagement run out. The review, therefore, indicates that the RMG industry still has a wide scope for gaining productivity improvements from more extensive and in-depth lean implementation. However, it is a subject for further research to what extent this is possible given the cultural context as well as the present managerial capabilities in the RMG industries located in developing countries.

Earlier research (Brännmark & Håkansson, 2012; Hasle et al., 2012) indicates that lean tends to have a negative effect on workers' health in manual assembly work which in several ways resembles the sewing tasks in the RMG industry. It could, therefore, be expected that such health risks could also be found as a consequence of lean implementation in the sewing industry. However, contrary to this expectation, our review shows with a few exceptions a trend towards positive effects. The studies have found positive effects of lean on a variety of items such as injuries, accidents, ergonomics, fatigue, teamwork, workers' commitment, turnover rate and absenteeism. Most of these items are referred to as psychosocial factors

(absenteeism, turnover intension, job involvement, job satisfaction, and human fatigue). It is interesting that such positive effects are also found in developing countries with a tradition for low workers involvement. It should be noted though that there are also some contradictory results, and it cannot be concluded as such that lean has a positive effect on psychosocial factors. As mentioned above, most of the studied lean cases are in initial phases and these findings may, therefore, be related to involvement of workers in the lean implementation.

As for RSI, it is well established from studies in industrialized countries (Vezina et al., 1992) that sewing carries a risk of long-term RSI. This risk is only included in two studies (Abeysekera & Illankoon, 2016; Marudhamuthu et al., 2011), with a focus on short-term effects and with mixed results. The risk of RSI and MSDs is, therefore, still unexplored, and there may very well be an important risk to consider and therefore a high priority for further studies. It is especially an open question what the long-term effect would be after years of exposure to a lean production set-up in garment.

Although the majority of the studies point towards positive effects, these results must be interpreted with caution. Most studies have weak associations due to methodological limitations such as single case studies and qualitative material. They also focus on short-term effects, and so far, the knowledge about long-term effects for both physical and psychosocial risks and general working conditions is very limited. However, it is at the same time important to emphasize that if lean had dramatic negative effects, it would probably have appeared in the reviewed studies.

At the same time, as we can conclude that lean tend to have a positive association with OHS and working conditions, it is evident that more research is needed. This is, in particular, the case for the long-term effect on lean on workers' health. Furthermore, more in-depth studies of the effects of various lean tools are needed. It may be for instance that 5S and value stream mapping have positive effects whereas waste removal based on-time and motion studies has more ambiguous effects on OHS. It is, in this context, important to make longitudinal studies with statistical comparison of lean and non-lean production systems.

6. Conclusion

There are so far still few studies of lean implementation in the RMG industry and its effects on productivity and OHS. But based on the review of the available studies, some preliminary conclusions can be drawn. There is significant evidence for a positive association between lean and productivity on several parameters such as efficiency, value-added time, change over time and quality. The studies are in most cases based on relatively short lean exposure time and it can therefore be expected that there may even be larger benefits to achieve in the long run. Such achievements would require though a more in-depth knowledge about implementation of lean in the RMG industry in a development country context.

For the effects of lean on OHS, the studies are more limited and based on weaker methodologies. Although there are studies showing mixed results, the tendency is clearly positive, and it seems likely that lean can have a positive to neutral effect on OHS in the short term. This effect will of course depend on the context of the implementation. Whereas more studies of the effects of lean on OHS and working conditions are needed, it is, in particular, important to emphasize that there are so far no studies of the long-term effect of

lean on OHS, in particular the risk of RSI. It would also be relevant to study the particular effects of the broad range of lean tools on OHS. As for practice, companies will benefit from lean implementation with productivity increases which may give a competitive advantage but focus for the companies should be secure a sustainable lean implementation which is integrating OHS. Management, therefore, needs to make a careful assessment of the possible effects on OHS associated with the different lean tools and practices, and thereby secure that appropriate measures to control the risk are applied. Otherwise, lean implementation can potentially increase the risk of detrimental effects on workers' health.

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References

- Abad, J., Lafuente, E., & Vilajosana, J. (2013). An assessment of the OHSAS 18001 certification process: Objective drivers and consequences on safety performance and labour productivity. *Safety Science*, 60, 47–56.
- Abeysekera, J., & Illankoon, P. (2016). The demands and benefits of ergonomics in Sri Lankan apparel industry: A case study at MAS holdings. *Work*, 55(2), 255–261.
- Ahmed, M., Islam, T., & Kibria, G. (2018). Study on 6S method and improving working environments in the garments industry. *International Journal of Scientific & Engineering Research*, 9(3), 737–754.
- Al-Jawazneh, B. E. (2011). The internal lean manufacturing practices at the apparel manufacturing companies in Jordan. *European Journal of Economics, Finance and Administrative Sciences* (43), 109–123. Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84255205321&partnerID=40&md5=7eaa6f59b825da0f195e6df4b022c5c2>
- Ansary, M. A., & Barua, U. (2015). Workplace safety compliance of RMG industry in Bangladesh: Structural assessment of RMG factory buildings. *International Journal of Disaster Risk Reduction*, 14(4), 424–437.
- Baughn, C. C., Bodie, N. L., & McIntosh, J. C. (2007). Corporate social and environmental responsibility in asian countries and other geographical regions. *Corporate Social Responsibility and Environmental Management*, 14(4), 189–205. doi:10.1002/(ISSN)1535-3966
- Berg, A., Hedrich, S., Kempf, H., & Tochtermann, T. (2011). *Bangladesh's ready-made garments landscape: The challenge of growth. Apparel, fashion & luxury practice*. McKinsey & Company, Inc.
- Brännmark, M., & Håkansson, M. (2012). Lean production and work-related musculoskeletal disorders: Overviews of international and Swedish studies. *Work-A Journal of Prevention Assessment & Rehabilitation*, 41, 2321–2328.

- Buckle, P. W., & Jason Devereux, J. (2002). The nature of work-related neck and upper limb musculoskeletal disorders. *Applied Ergonomics*, 33(3), 207–217.
- Carvalho, C. P., Carvalho, D. S., & Silva, M. B. (2019). Value stream mapping as a lean manufacturing tool: A new account approach for cost saving in a textile company. *International Journal of Production Management and Engineering*, 7(1), 1.
- Chiromo, F., Nel, A., & Sebele, T. O. (2015). Lean manufacturing challenges in a South African clothing company. In P. L. Thopil (Ed.), *IAMOT 2015-24th International Association for Management of Technology Conference: Technology, Innovation and Management for Sustainable Growth, Proceedings* (pp. 1966–1974). Graduate School of Technology Management, University of Pretoria. Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84959309141&partnerID=40&md5=0f47a200f76b7b9655559534593dbfa3>
- Gaiardelli, P., Resta, B., & Dotti, S. (2018). Exploring the role of human factors in lean management. *International Journal of Lean Six Sigma*. doi:10.1108/IJLSS-08-2017-0094
- Gamage, J., Vilasini, N., Perera, C., & Wijenatha, L. (2012). Impact of lean manufacturing on performance and organisational culture: A case study of an apparel manufacturer in Sri Lanka. In *The third international conference on Engineering, Project and Production Management (EPPM), UK* (pp. 423–436). doi:10.1016/j.juro.2012.07.025
- Gamage, P., Jayamaha, N. P., & Grigg, N. P. (2016). Acceptance of Taguchi's quality philosophy and practice by lean practitioners in apparel manufacturing. *Total Quality Management and Business Excellence*, 28(11), 1–17.
- Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, 26(2), 91–108.
- Gupta, S., & Jain, S. K. (2013). A literature review of lean manufacturing. *International Journal of Management Science and Engineering Management*, 8(4), 241–249.
- Harrison, B. (1994). *Lean and mean. The changing landscape of corporate power in the age of flexibility*. New York: The Guildford Press.
- Hasle, P. (2014). Lean production - An evaluation of the possibilities for an employee supportive lean practice. *Human Factors and Ergonomics in Manufacturing*, 24(1), 40–53.
- Hasle, P., Bojesen, A., Jensen, P. L., Bramming, P., Jensen, L., Bramming, P., ... Bramming, P. (2012). Lean and the working environment: A review of the literature. *International Journal of Operations & Production Management*, 32(7), 829–849.
- Hasnin, N., & Ahsan, M. (2016). Employee training and operational risks : The case of RMG sector in Bangladesh. *World Journal of Social Sciences*, 6(2), 71–81.
- Hodge, G. L., Goforth Ross, K., Joines, J. A., & Thoney, K. (2011). Adapting lean manufacturing principles to the textile industry. *Production Planning & Control*, 22(3), 237–247.
- Islam, M. F. (2015). Job dissatisfaction of Bangladeshi garment workers : Identification of causes & remedies. *Stamford Journal of Economics*, 2(1), 114–127.
- Islam, M. M., & Adnan, A. (2016). Improving ready-made garment productivity by changing worker attitude. *European Scientific Journal*, 12(4), 436–444.
- Jackson, P. R., & Mullarkey, S. (2000). Lean production teams and health in garment manufacture. *Journal of Occupational Health Psychology*, 5(2), 231–245.
- Kader, S., & Akter, M. K. M. (2014). Analysis of the factors affecting the lead time for export of readymade apparels from Bangladesh; Proposals for strategic reduction of lead time. *European Scientific Journal*, 10(33), 268–283.
- Kaur, P., Marriya, K., & Kashyap, R. (2016). Assessment of lean initiatives: An investigation in the Indian apparel export industry. *Indian Journal of Management*, 9(9), 52–66.
- Kumar, B. S., & Sampath, V. (2012). Garment manufacturing through lean initiative-an empirical study on WIP fluctuation in T-shirt production unit. *International Journal of Lean Thinking*, 3(2), 102–116.
- Kumar, D. V., Mohan, G. M., & Mohanasundaram, K. M. (2019). Lean tool implementation in the garment industry. *Fibres and Textiles in Eastern Europe*, 27(2(134)), 19–23.
- Landsbergis, P. A., Cahill, J., & Schnall, P. L. (1999). The impact of lean production and related new systems of work organization on worker health. *Journal of Occupational Health Psychology*, 4(2), 108–130.

- Liker, J. K. (2004). *The Toyota way: 14 management principles from the World's greatest manufacturer*. *Journal of chemical information and modeling* (Vol. 53). New York: McGraw Hill. doi:10.1017/CBO9781107415324.004
- Locke, R., & Romis, M. (2007). Improving work conditions in a global supply chain. *MIT Sloan Management Review*, 48(2), 54–62. Retrieved from <http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=23701513&site=ehost-live>
- Locke, R. M., Qin, F., & Brause, A. (2007). Does monitoring improve labor standards? Lessons from Nike. *Industrial and Labor Relations Review*, 61(2), 3–31.
- Maalouf, M., Hasle, P., Vang, J., & Hoque, I. (2019). *Sustaining lean in organizations through the management of tensions and paradoxes*. In F. Silva & L. C. Ferreira (Eds.), *Lean manufacturing: Implementation, opportunities and challenges*. New York, NY: Nova Science Publishers.
- Marudhamuthu, R., Krishnaswamy, M., & Pillai, D. M. (2011). The development and implementation of lean manufacturing techniques in Indian garment industry. *Jordan Journal of Mechanical & Industrial Engineering*, 5(6), 527.
- Muggleton, J. M., Allen, R., & Chappell, P. H. (1999). Hand and arm injuries associated with repetitive manual work in industry: A review of disorders, risk factors and preventive measures. *Ergonomics*, 42 (5), 714–739.
- Nargis, N. (2013). An analysis of export and import growth of Bangladesh: A study on ready-made garment (RMG). *Daffodil International University Journal of Business and Economics*, 7(1), 187–198.
- Ohno, T. (1988). Toyota production system. *International Journal of Operations*, 4. doi:10.1108/eb054703
- Ozturk, N., & Esin, M. N. (2011). Investigation of musculoskeletal symptoms and ergonomic risk factors among female sewing machine operators in Turkey. *International Journal of Industrial Ergonomics*, 41(6), 585–591.
- Pagell, M., Klassen, R., Johnston, D., Shevchenko, A., & Sharma, S. (2015). Are safety and operational effectiveness contradictory requirements: The roles of routines and relational coordination. *Journal of Operations Management*, 36, 1–14.
- Pakdil, F., & Leonard, K. M. (2015). The effect of organizational culture on implementing and sustaining lean processes. *Journal of Manufacturing Technology Management*, 26 (5), 725–743.
- Quddus, M. A., & Nazmul Ahsan, A. M. M. (2014). A shop-floor kaizen breakthrough approach to improve working environment and productivity of a sewing floor in RMG industry. *Journal of Textile and Apparel, Technology and Management*, 8(4). Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84902281416&partnerID=40&md5=571354f0b44d7530b11ee347da1308f9>
- Rahman, A., & Hossain, S. (2010). Compliance practices in garment industries in Dhaka city. *Journal of Business and Technology (Dhaka)*, 5(02), 71–87.
- Raju, P. G., & Mahato, M. M. (2014). Impact of longer usage of lean manufacturing system (Toyotism) on employment outcomes – a study in garment manufacturing industries in India. *International Journal of Services and Operations Management*, 18(3), 305.
- Rakib, M. A., & Adnan, A. (2015). Challenges of ready-made garments sector in Bangladesh : Ways to overcome. *BUFT Journal*, 3, 77–90.
- Saha, P., & Mazumder, S. (2015). Impact of working environment on less productivity in RMG industries: A study on Bangladesh RMG sector. *Global Journal of Management and Business Research: G Interdisciplinary Volume*, 15(2), 19–26.
- Sakouhi, A., & Nadeau, S. (2016). Integration of occupational health and safety into lean manufacturing: Quebec aeronautics case study. *American Journal of Industrial and Business Management*, 06(11), 1019–1031.
- Sealetsa, O. J., & Thatcher, A. (2011). Ergonomics issues among sewing machine operators in the textile manufacturing industry in Botswana. *Work*, 38(3), 279–289.
- Shah, R., & Ward, P. T. (2007). Defining and developoing measures of lean production. *Journal of Operations Management*, 25(4), 785–805.
- Silva, S. K. P. N. (2012). Applicability of value stream mapping (VSM) in the apparel industry in Sri Lanka. *International Journal of Lean Thinking*, 3(1), 36–56.

- Sparrow, P., & Otaeye-Ebede, L. (2014). Lean management and HR function capability: The role of HR architecture and the location of intellectual capital. *The International Journal of Human Resource Management*, 25(21), 2892–2910.
- Spear, S., & Bowen, H. K. (1999). Decoding the DNA of the Toyota production system. *Harvard Business Review*, 77(5), 96–106. <https://doi.org/http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=2216294&site=ehost-live>
- Stewart, P., Richardson, M., Danford, A., Murphy, K., Richardson, T., & Wass, V. (2009). *WE sell our time no more – workers' struggle against lean production in the British car industry*. London: Pluto Press.
- Taj, S. (2008). Lean manufacturing performance in China: Assessment of 65 manufacturing plants. *Journal of Manufacturing Technology Management*, 19(2), 217–234. Retrieved from <http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=31398496&site=ehost-live>
- Tompa, E., Robson, L., Sarnocinska-Hart, A., Klassen, R. D., Shevchenko, A., Sharma, S., & Pagell, M. (2016). Managing safety and operations – the effect of joint management system practices on safety and operational outcomes. *Journal of Occupational & Environmental Medicine*, 58(3), e80–e89.
- Vest, J. R., & Gamm, L. D. (2009). A critical review of the research literature on Six Sigma, lean and StuderGroup's hardwiring excellence in the United States: The need to demonstrate and communicate the effectiveness of transformation strategies in healthcare. *Implementation Science*, 4.
- Vezina, N., Tierney, D., & Messing, K. (1992). When is light work heavy? Components of the physical workload of sewing machine operators working at piecework rates. *Applied Ergonomics*, 23(4), 268–276.
- Vijayakumar, G., & Robinson, Y. (2016). Impacts of lean tools and techniques for improving manufacturing performance in garment manufacturing scenario : A case study. *International Journal of Advanced Engineering Technology*, 7(2), 251–260.
- Von Thiele Schwarz, U., Hasson, H., & Tafvelin, S. (2016). Leadership training as an occupational health intervention: Improved safety and sustained productivity. *Safety Science*, 81, 35–45.
- Westgaard, R. H., & Winkel, J. (2011). Occupational musculoskeletal and mental health: Significance of rationalization and opportunities to create sustainable production systems – A systematic review. *Applied Ergonomics*, 42(2), 261–296.
- Wickramasinghe, D., & Wickramasinghe, V. (2011a). Differences in organizational factors by lean duration. *Operations Management Research*, 4(3–4), 111–126.
- Wickramasinghe, D., & Wickramasinghe, V. (2011b). Perceived organisational support, job involvement and turnover intention in lean production in Sri Lanka. *International Journal of Advanced Manufacturing Technology*, 55(5–8), 817–830.
- Wickramasinghe, G., & Wickramasinghe, V. (2017). Implementation of lean production practices and manufacturing performance: The role of lean duration. *Journal of Manufacturing Technology Management*, 28(4). JMTM-08-2016-0112. doi:10.1108/JMTM-08-2016-0112
- Wickramasinghe, G. L. D., & Perera, A. (2016). Effect of total productive maintenance practices on manufacturing performance investigation of textile and apparel manufacturing firms. *Journal of Manufacturing Technology Management*, 27(5), 713–729.
- Wickramasinghe, G. L. D., & Wickramasinghe, V. (2016). Effects of continuous improvement on shop-floor employees' job performance in lean production The role of lean duration. *Research Journal of Textile and Apparel*, 20(4), 182–194.
- Witchell, S., & Symington, P. (2013, February). China plus one. *FTI Journal*. Retrieved from <http://ftijournal.com/article/china-plus-one>
- Womack, J. P., & Jones, D. T. (1996). *Lean thinking*. New York: Simon & Schuster.
- Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world*. New York: Rawson Associates.
- Zhang, M., Kong, X. X., & Ramu, S. C. (2015). Asia pacific business review. *The Transformation of the Clothing Industry*, 2381. (Special). doi:10.1080/13602381.2014.990204
- Zhang, X., Wang, Z., & Li, T. (2010). The current status of occupational health in China. *Environmental Health and Preventive Medicine*, 15(5), 263–270.